

# Biodiesel from Castor Oil

Subjects: [Energy & Fuels](#)

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An attractive alternative to the use of fossil fuels is biodiesel, which can be obtained from a variety of feedstock through different transesterification systems such as ultrasound, microwave, biological, chemical, among others. The efficient and cost-effective biodiesel production depends on several parameters such as free fatty acid content in the feedstock, transesterification reaction efficiency, alcohol: oil ratio, catalysts type, and several parameters during the production process. However, biodiesel production from vegetable oils is under development, causing the final price of biodiesel to be higher than diesel derived from petroleum. An alternative to decrease the production costs will be the use of economical feedstocks and simple production processes. Castor oil is an excellent raw material in terms of price and quality, but especially this non-edible vegetable oil does not have any issues or compromise food security. Recently, the use of castor oil has attracted attention for producing and optimizing biodiesel production, due to the high content of ricinoleic fatty acid and the possibility to esterify with only methanol, which assures low production costs. Additionally, biodiesel from castor oil has different advantages over conventional diesel. Some of them are biodegradable, non-toxic, renewable, they can be used alone, low greenhouse gas emission, among others. This review discusses and analyzes different transesterification processes, technologies, as well as different technical aspects during biodiesel production using castor oil as a feedstock.

[Biodiesel](#) [Castor oil](#) [Ricinus communis](#)

## 1. Vegetable Oils to Produce Biodiesel

During biodiesel production it is necessary to consider the ecological and economic benefits during its production and its use as a biofuel. The biodiesel production cost depends greatly on the feedstock price. It is advisable to produce biodiesel in the same regions where the feedstock is located to decrease costs and environmental footprint related to feedstock transport <sup>[1]</sup>.

The primary feedstock to produce biodiesel is raw vegetable oils and used cooking oils, as well as different animal grease. To produce biodiesel, several vegetable oils can be used such as rapeseed, soybean, cotton, peanut, corn, olive, sesame, safflower, and sunflower <sup>[2]</sup>. Some examples of tropical oily crops containing good quality oil that can be transesterified are *Raphanus sativus* (radish), *Jatropha curcas* (physic nut), *Cyperus esculentus* (tiger nut), *Simmondsia chinensis* (jojoba), *Gratissima persea* (avocado), *Lupinus albus* (white lupin), *Caryocar brasiliense* (pequi), the palm species *Acrocomia aculeata*, *Mauritia flexuosa*, *Elaeis oleifera*, *Syagrus coronata*, *Attalea speciosa*, and *R. communis* (castor seeds) <sup>[3]</sup>. Table 1 shows some raw materials used in biodiesel production.

However, the most common feedstock is raw vegetable oils extracted from energy and non-energy crops such as soybean, rapeseed, sunflower, coconut, and palm oil, which are cultivated around the world <sup>[4]</sup>.

**Table 1.** Examples of oil-feedstock used in biodiesel production.

Feedstock Source (Oil Content, %)	Characteristics	Advantages	Disadvantages	Ref.
Castor beans (46–55)	Liquid at room temperature, light yellow color, and slightly pungent *US\$824/tonne of oil	Transesterification can be performed at room temperature Miscible in alcohol Non-edible Low acid value High flashpoint	Generation of toxic solid waste High viscosity Decrease fuel atomization	<sup>[5]</sup> <sup>[6]</sup>
Jatropha (34–60)	Colorless after extraction (fresh) and pale yellow after standing time, liquid at room temperature **US\$250/tonne of oil	Biodiesel obtained is stable during storage Non-edible High cetane number, good oxidation stability, low viscosity	Engine corrosion due to free fatty acids Generation of toxic solid waste High cloud point Not suitable at low temperature High acid value	<sup>[7]</sup> <sup>[8]</sup>
Soybean (12–22)	Fresh has a pale light color, and dark after storage, liquid at room temperature ***US\$746/tonne of oil	The yield of 98% crude biodiesel in refined oils High thermal stability Low viscosity	The high cost of production Biodiesel production in long-term is unsustainable Edible High acid value	<sup>[9]</sup> <sup>[10]</sup>
Sunflower (38–50)	Refined has a clear and vaguely yellowish-brown color Liquid at room temperature ***US\$689/tonne of oil	Low viscosity	Used to produce food and fiber Biodiesel production in long-term is unsustainable Edible High acid value	<sup>[10]</sup> <sup>[11]</sup>
Palm (18–40)	Semi-solid at room temperature, reddish and clear color, depending on extraction source (pulp or kernel) ***US\$535/tonne of oil	96% yield of crude biodiesel in refined oils Cheap feedstock Good oxidation stability Acceptable ratio of	High cloud point Conversion to biodiesel may not be sustainable long term Edible	<sup>[9]</sup> <sup>[12]</sup>

Feedstock Source (Oil Content, %)	Characteristics				Advantages		Disadvantages		Ref.
Oil	Depends on the cooking process				Low cloud point		High ratio of acid		
	Fatty Acid Composition (wt%)								Ref.
	Saturated		Monounsaturated		Polyunsaturated				
	C14:0	C16:0	C18:0	C18:1 cis-9	C18:1*	C18:2	C18:3	Others	
Castor	-	1.1	1.0	3.3	87.7	4.7	0.7	1.5	[20]
Jatropha	-	12.80	6.20	39.94	-	45.40	-	<1.0	[8]
Soybean	-	11.46	3.08	23.30	-	53.32	0.31	8.53	[20][21]
Sunflower	0.08	8.03	3.26	29.27	-	59.32	-	0.04	[23]
Palm	0	46.8	3.80	37.60	-	10.50	-	1.3	[24]
Canola	-	3.90	1.10	64.40	-	20.4	9.60	0.6	[25]

*communis* meets most of the properties considered desirable to produce useful feedstocks in biodiesel production, except the high viscosity of oil that may limit its use. They are composed mainly of triglycerides and slight amounts of free fatty acids. Table 2 shows the most abundant fatty acids in vegetable oils (palmitic, oleic, and linoleic acids). Vegetable oils as a feedstock for biodiesel production is a promising source. However, most of them are used for food purposes and their use is restricted for this activity. Hence, castor oil for biofuel production shows several advantages over conventional edible oils. Due to its non-edible oil and its main fatty acid (ricinoleic acid) with hydroxyl groups that have a higher solubility in alcohol, it represents a great advantage to obtain methyl esters at low temperatures.

## 2. Castor Oil Biodiesel Production and Features

Castor oil is a light yellow and slightly pungent liquid, that is used in several industries around the world. Some of these industries are pharmaceutical, cosmetic, chemical, among others. However, in recent years this non-edible vegetable oil has been investigated to produce biofuels, specifically biodiesel. The above is due to the physicochemical, chemical, and physical characteristics of castor oil (Table 3) give to biodiesel when this is used as a feedstock.

Table 3. Main characteristics of raw castor oil.

Parameter	Zhang et al. [26]	Molefe et al. [27]	Kaur and Bhaskar [28]
Acid value /(mg.g <sup>-1</sup> )	1	2.07	<4
Saponification value /(mg.g <sup>-1</sup> )	180	175	178

Iodine value (g/100 g)	86	84	85
Refractive index (n <sub>20</sub> D)	1.48	1.48	1.47
Relative density (g/cm <sup>3</sup> )	0.956	0.961	0.965
Flashpoint (°C)	322	145	229
Specific heat (kJ/kg/K)	nd	0.089	0.089
Ricinic acid (%wt)	88	89.5	87-90
Oleic acid (%wt)	7	3	2-7
Linoleic acid (%wt)	5	4	1-5
Linolenic acid (%wt)	1	0.3	nd

nd: not determined

The process to produce biodiesel from oilseeds usually starts with oil extraction using a mechanical press or solvents. Figure 1 shows a general scheme for castor oil extraction. To perform mechanical oil extraction from castor beans it is necessary to consider the high oil viscosity. On the contrary, this is not necessary if the oil is extracted with solvents, but an evaporation step would be needed to recover the solvent. After extraction, different refining steps such as filtration, centrifugation, deodorization, discoloration, or winterization would be necessary to improve biodiesel quality.

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Product	Kinematic Viscosity (mm <sup>2</sup> /s at 40 °C)	Density (kg/m <sup>3</sup> )	Acid Value (mgKOH/g)	Flash Point (°C)	Water Content (%)	Calorific Value (MJ/kg)	Cetane Number	Cloud Point (°C)	Pour Point (°C)	Iodine Value (gI <sub>2</sub> /100 g)	Ref.
*Biodiesel from castor oil	23	960	13.12	262	nd	30.18	nd	3	-13	nd	[32]
	14	926	nd	164	nd	37.90	nd	-23	nd	nd	[33]
	15	946	0.63	194	0.15	38.34	43	nd	-30	nd	[34]
	26	961	1.19	nd	0.31	nd	nd	nd	nd	80.5	[28]
	18	920	0.25	170	0.006	39.5	nd	nd	nd	nd	[35]
**Biodiesel according ASTM D 6751-06a	14	923	nd	273.1	nd	37.34	50	nd	nd	83.40	[36]
	1.9-6.0	860-900	≤0.50	≥130	≤0.50	nd	≥47	-3-12	-15-10	nd	[37]
**Biodiesel according EN 14214	3.5-5.0	860-900	≤0.50	≥101	≤0.50	nd	≥51	nd	nd	nd	[37]
***Fossil Diesel	2.5-4.5	820-860	nd	68-80	nd	≥45.56	≥46	-15-5	-35-15	nd	[38]

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Moreover, non-edible vegetable oil from castor bean seeds is a suitable feedstock to replace 40%–50% of edible oil currently used in biodiesel production. Furthermore, the ricinoleic fatty acid offers advantages to the transesterification process such as high miscibility in alcohol, low reaction temperature, low iodine content, and low freezing point. Biodiesel from castor oil offers a wide range of benefits, among them, is that, it is biodegradable, non-toxic, renewable, and safe handling, it can be used alone, and it presents low greenhouse gas emission, high flash point, and similar energy content to fossil diesel. However, when castor biodiesel is used without blending (B100) some challenges are present, for example, the high viscosity and high density decrease its ignition and can be a potential risk for vehicle engines. Finally, it is necessary to improve the transesterification process to decrease the final price and can be competitive with petrodiesel cost.
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